Simulation of electrical wire explosion by nanosecond current pulse

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MHD simulation of wire explosion

$$\frac{d\rho}{dt} + \rho \quad \vec{V} = \qquad\qquad \rho\frac{d\vec{V}}{dt} = \qquad P + \frac{}{c}\left[\vec{j}\times\vec{B}\right]$$

$$\rho\frac{d\varepsilon_e}{dt} = -P_e \quad \vec{V} - \quad \vec{Q}_e - Q_{ei} + G_J - G_R$$

$$\rho\frac{d\varepsilon_i}{dt} = -P_i \quad \vec{V} - \quad \vec{Q}_i - Q_{ei} \qquad \vec{Q}_{e\,i} = -\kappa_{e\,i} \quad \left(T_{e\,i}\right)$$

Diffusion of magnetic field:

$$\frac{\partial\vec{B}}{\partial t} = -c \quad \vec{E} \qquad \vec{B} = \qquad \vec{j} = \sigma\left(\vec{E} + \frac{}{c}\left[\vec{V}\times\vec{B}\right]\right) = \frac{c}{\pi} \quad \vec{B}$$

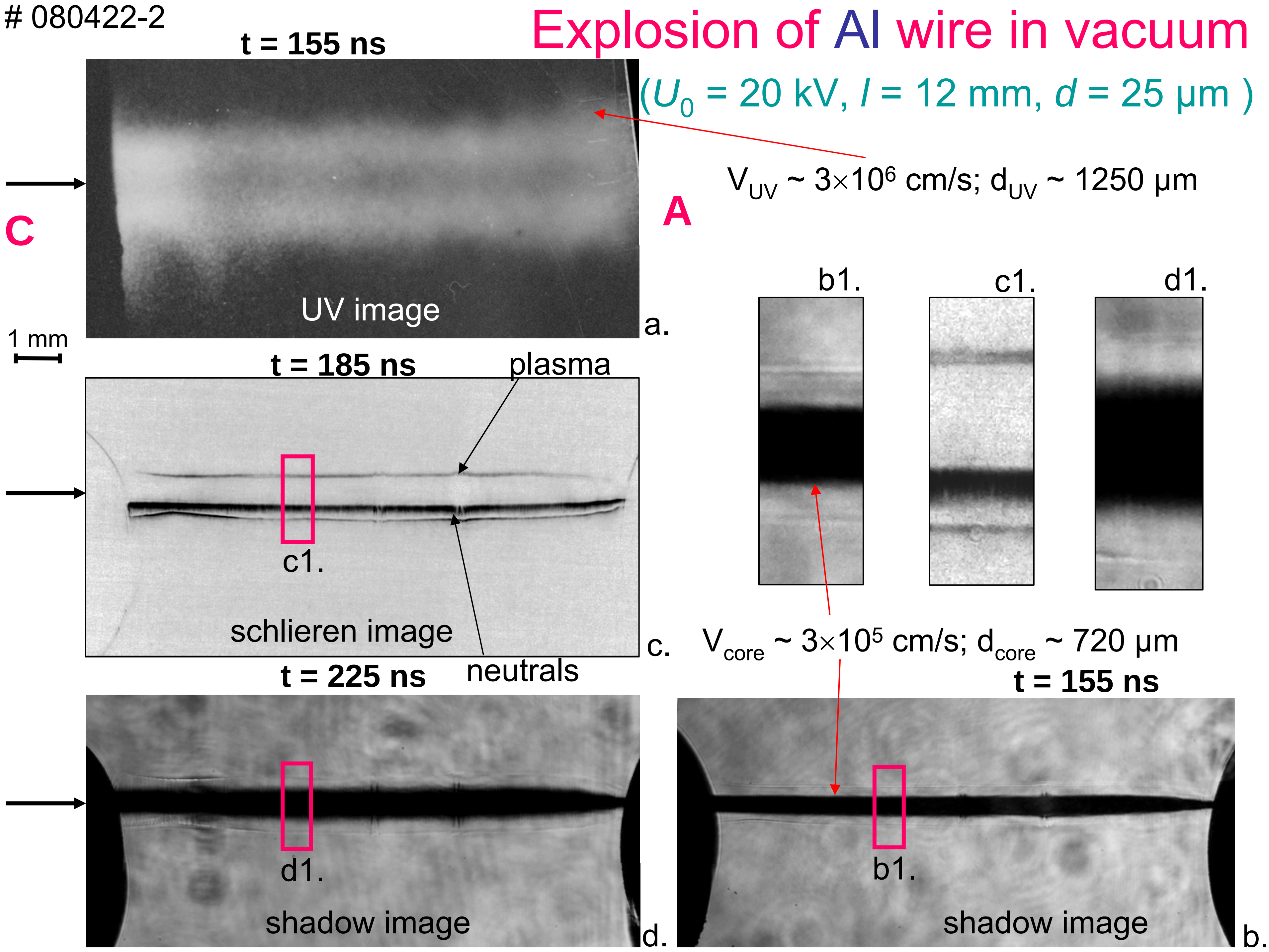
Properties of matter :

$$P(\rho\ T) = P_e(\rho\ T_e) + P_i(\rho\ T_i) \quad \varepsilon(\rho\ T) = \varepsilon_e(\rho\ T_e) + \varepsilon_i(\rho\ T_i) \qquad \sigma = \sigma(\rho\ T)$$

V.A.Gasilov et al Mathematical Modelling, 2003, v. 15, No 9, pp. 107-124

Explosion of Al wire in vacuum

(U_0 = 20 kV, l = 12 mm, d = 25 µm)



Estimation of matter parameters

Al

155 ns – core

d_{core} ~ 720 μm

v_{core} ~ 2.5×10^5 cm/s

n ~ 7×10^{19} cm^{-3}

T ~ 9×10^3 K

(T_{cr} ~ 8×10^3 K)

155 ns – corona

d_{UV} ~ 1200 μm

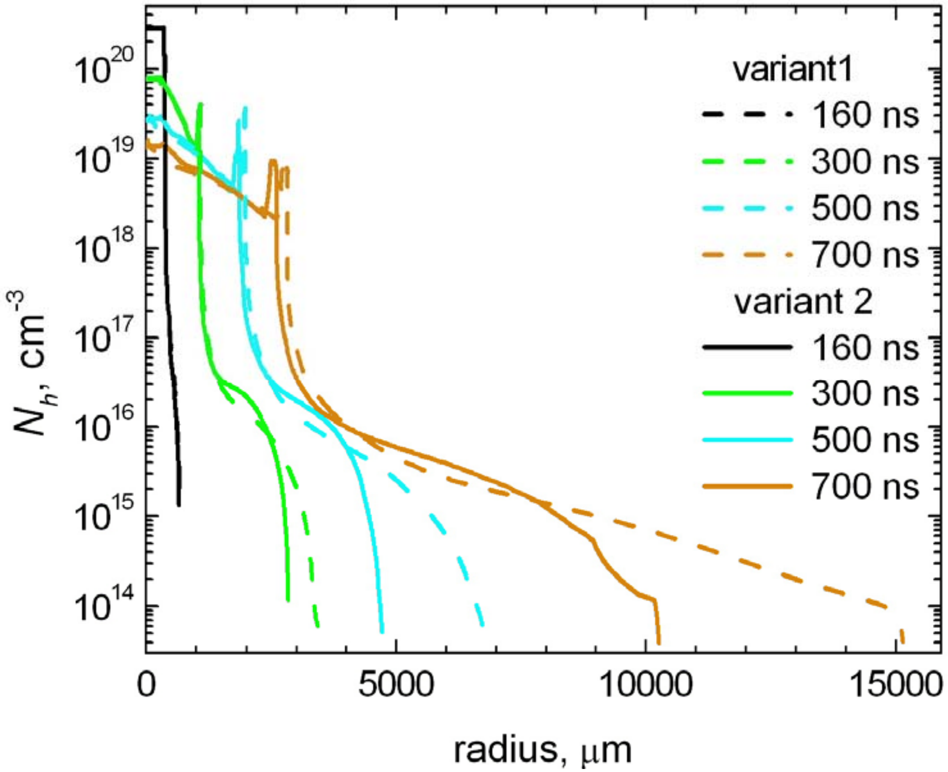
v_{UV} ~ 2.5×10^6 cm/s

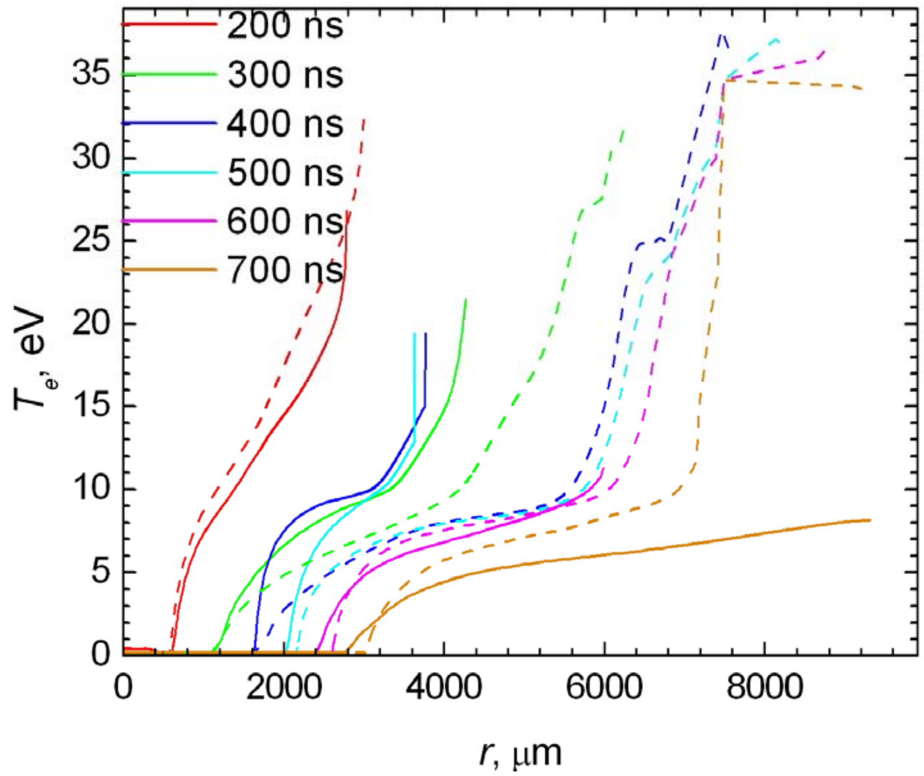
ε_{UV} < 180 eV

n_e << 10^{18} cm^{-3}

S.I. Tkachenko, A.P. Mingaleyev, V.M. Romanova, A.E. Ter-Oganesyan,
T.A. Shelkovenko, S.A. Pikuz. Plasma Physics Reports, 2009, Vol. 35, No. 9, pp. 734.

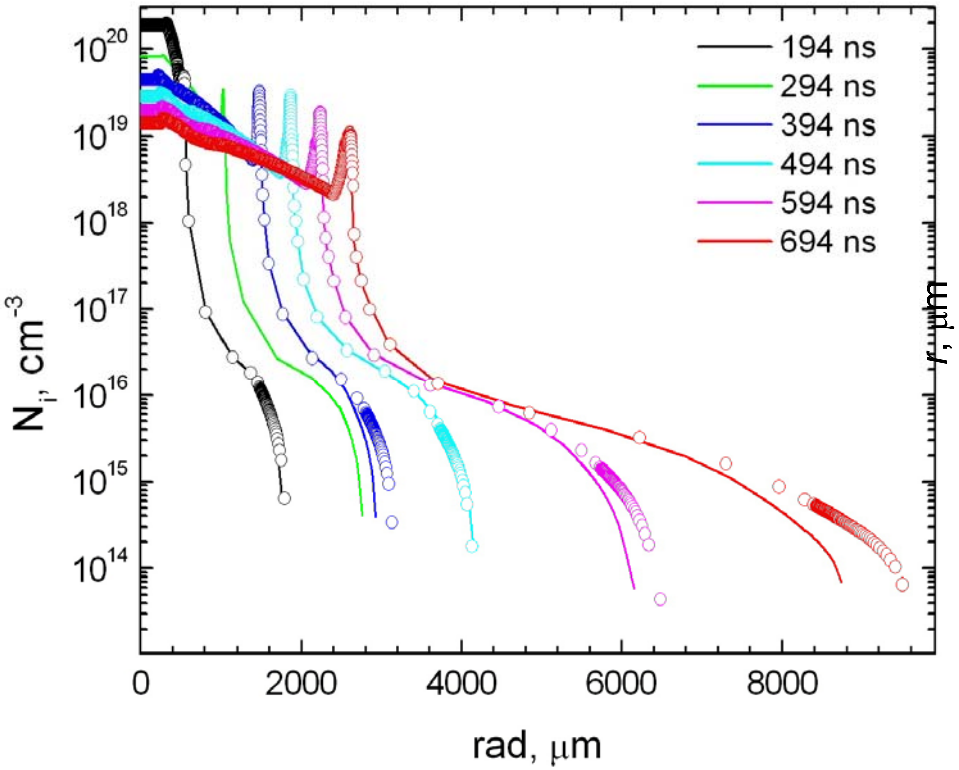
Numerical data

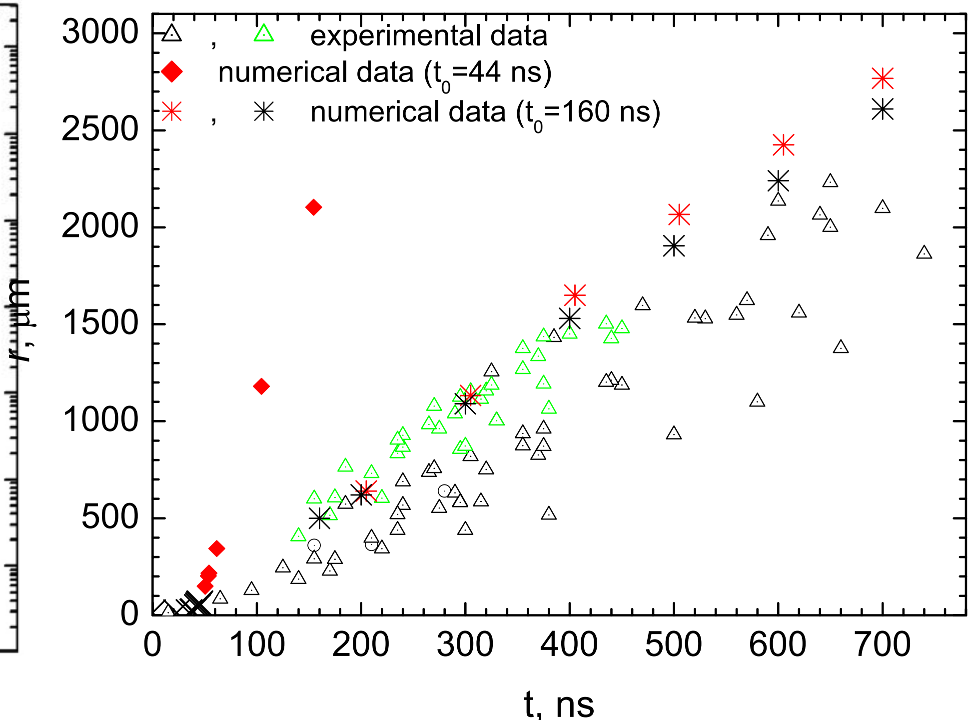




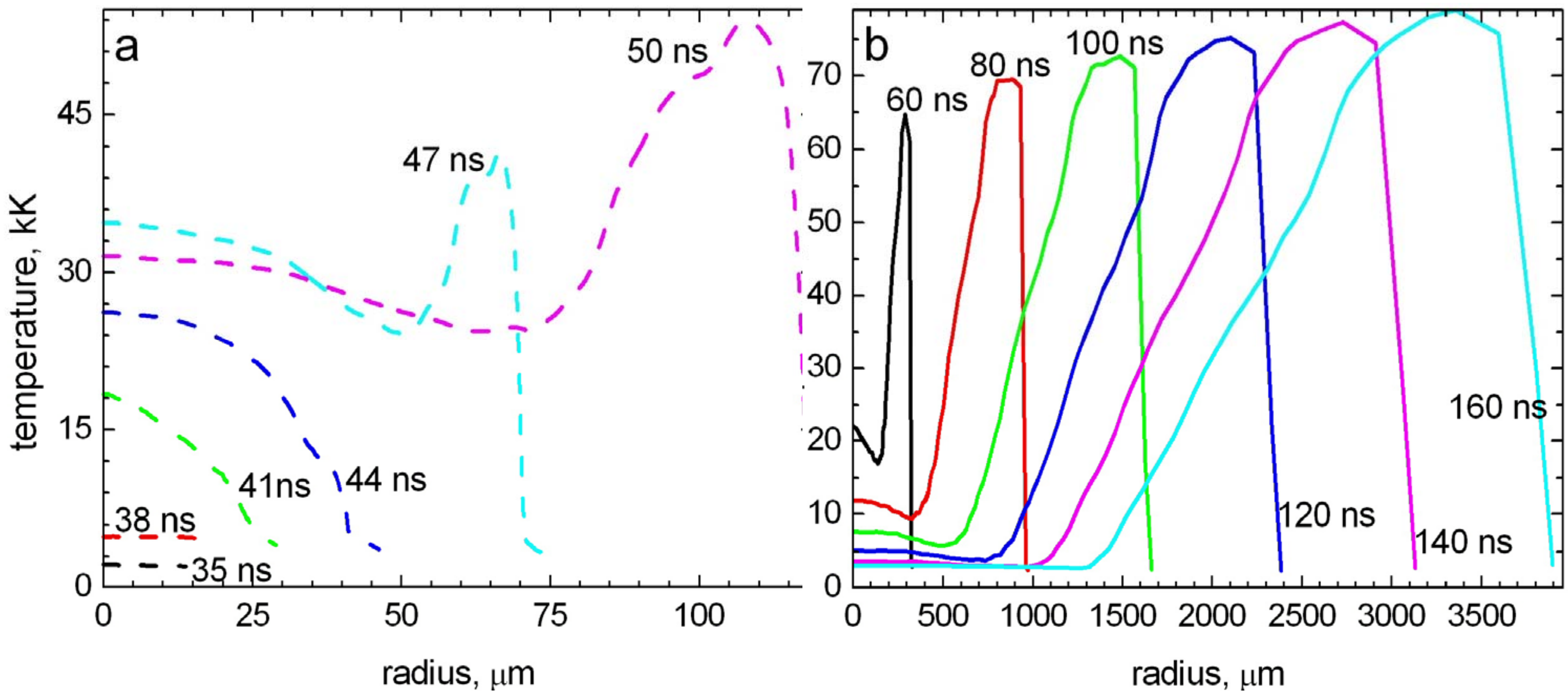
A.F. Nikiforov, V.G.Novikov, V.B.Uvarov, Quantum-Statistical Models of Hot Dense Matter and Methods for Computation Opacity and Equation of State. Fismatlit, Moscow, 2000

Comparison of experimental and numerical data



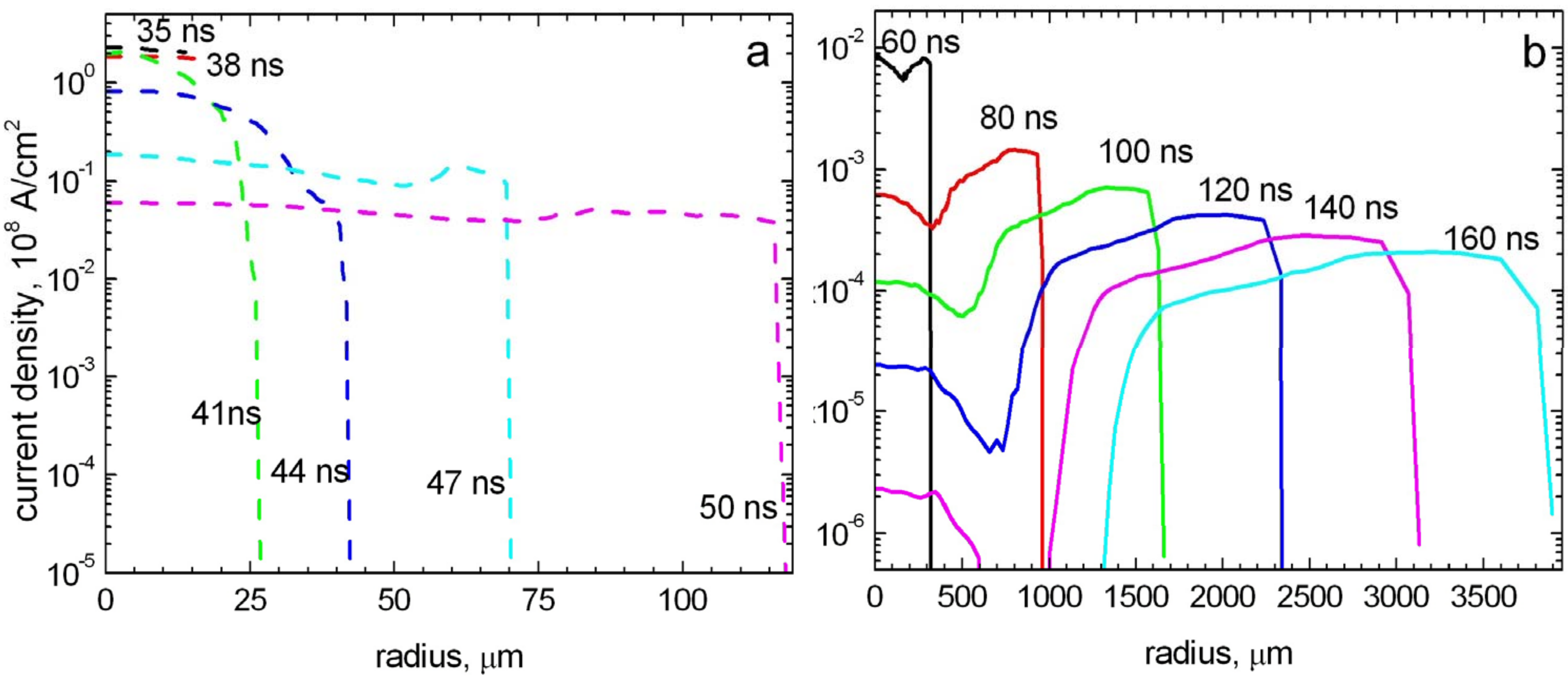


Numerical results: “cold start” simulation

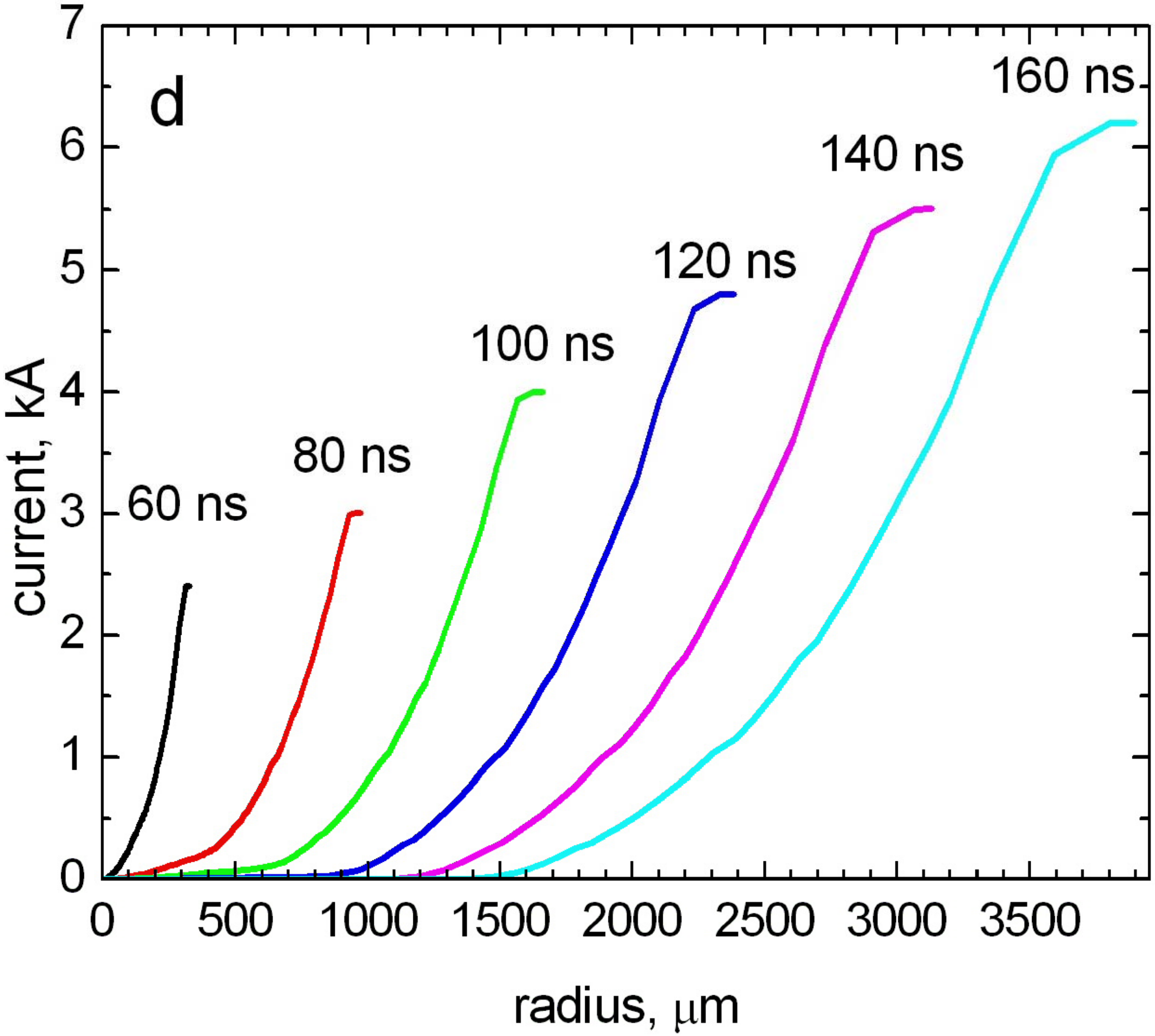


V. E. Fortov, K. V. Khishchenko, P. R. Levashov, and I. V. Lomonosov, Nucl. Instr. Meth. Phys. Res. *A* 415:604, 1998

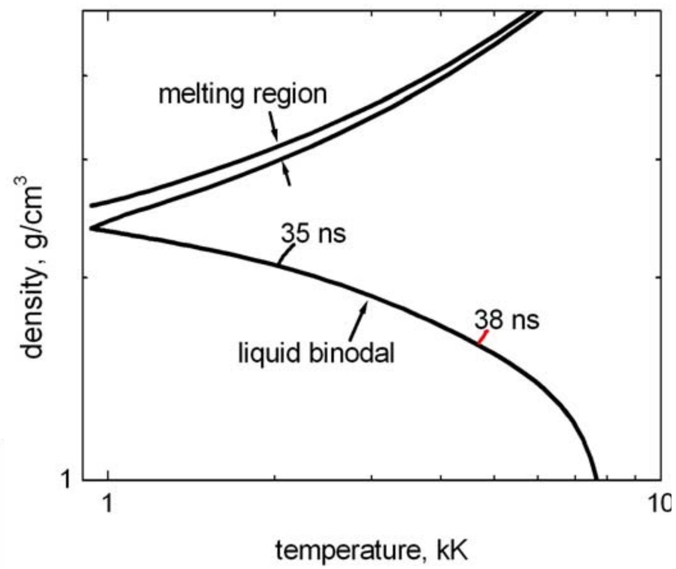
Numerical results: "cold start" simulation

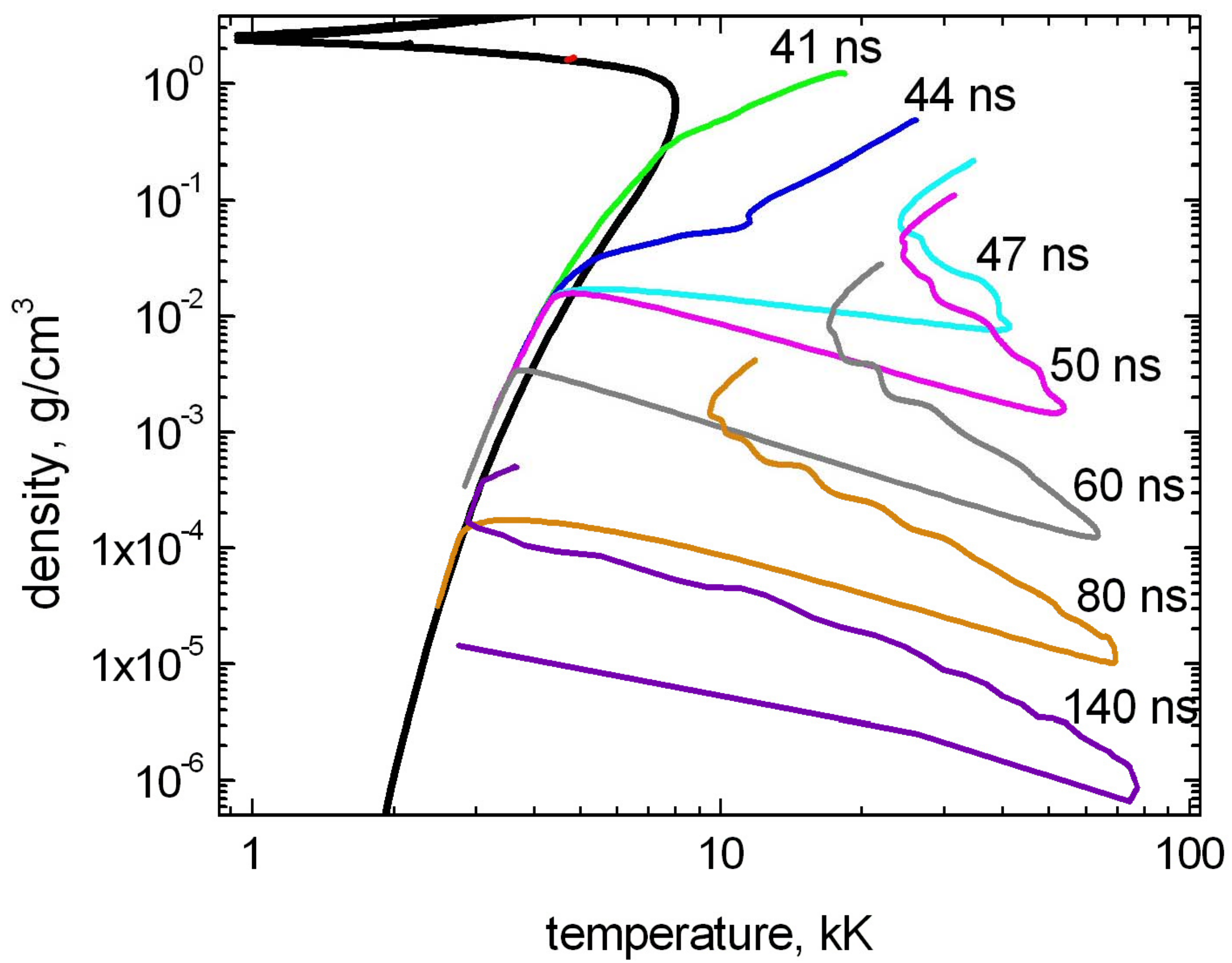


Numerical results: “cold start” simulation

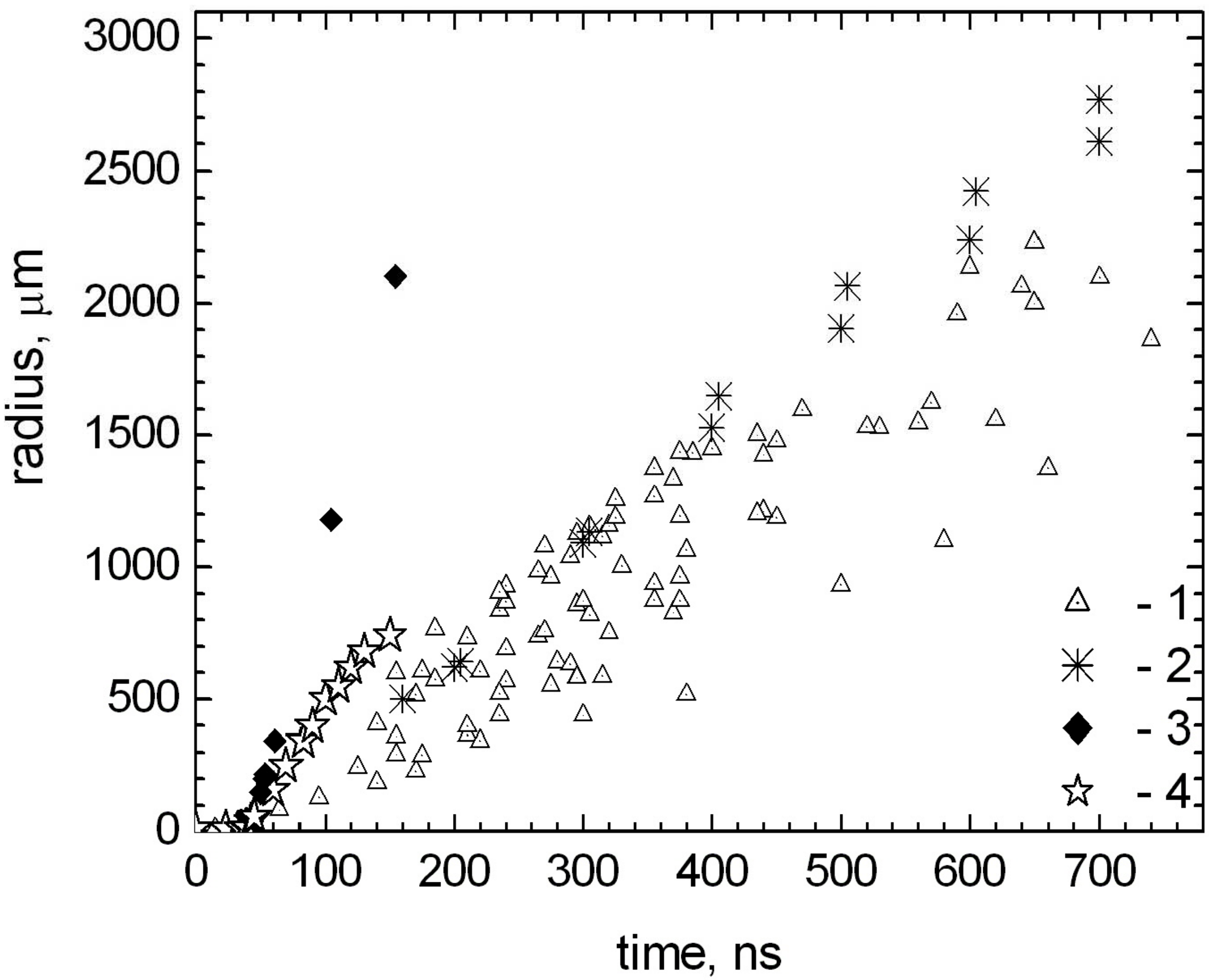


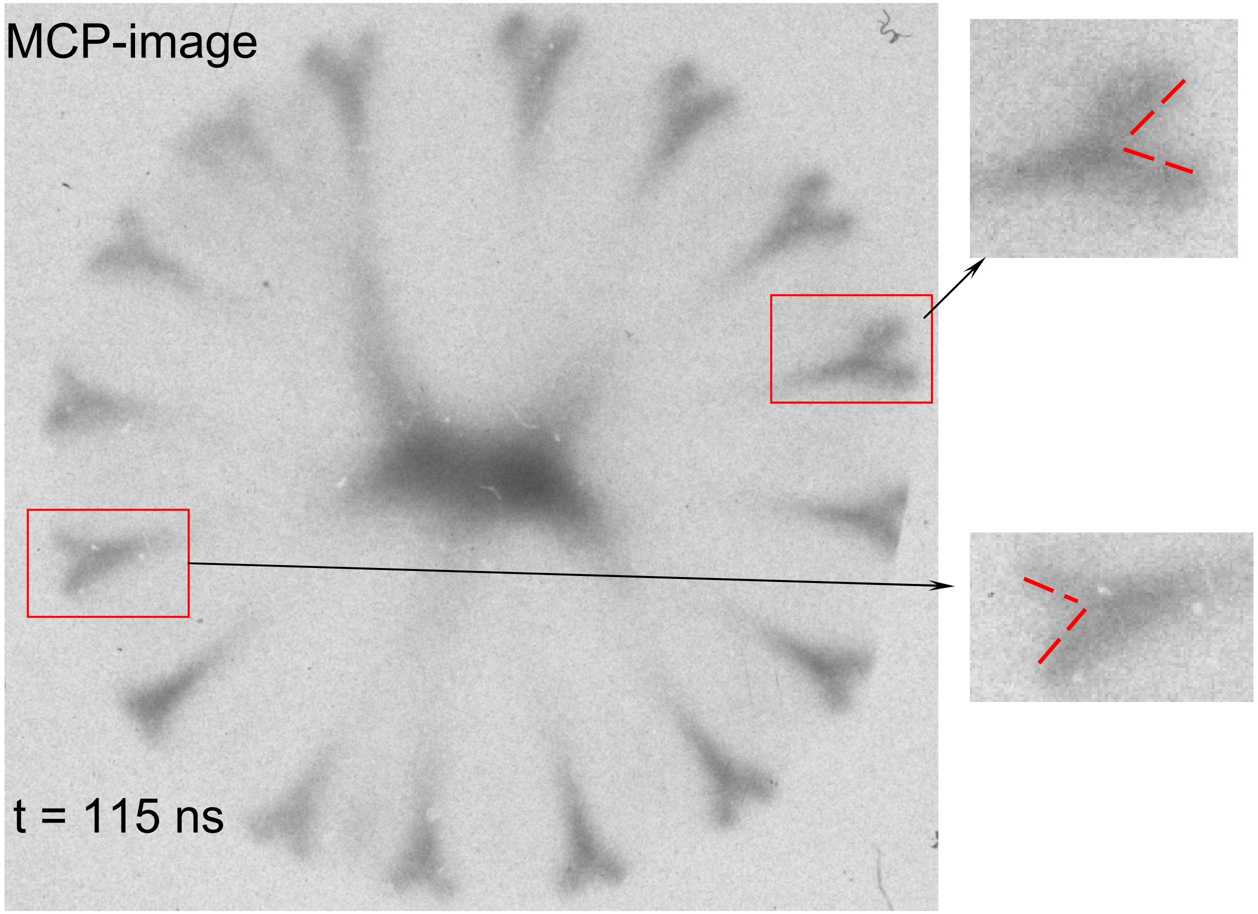
Numerical results: "cold start" simulation





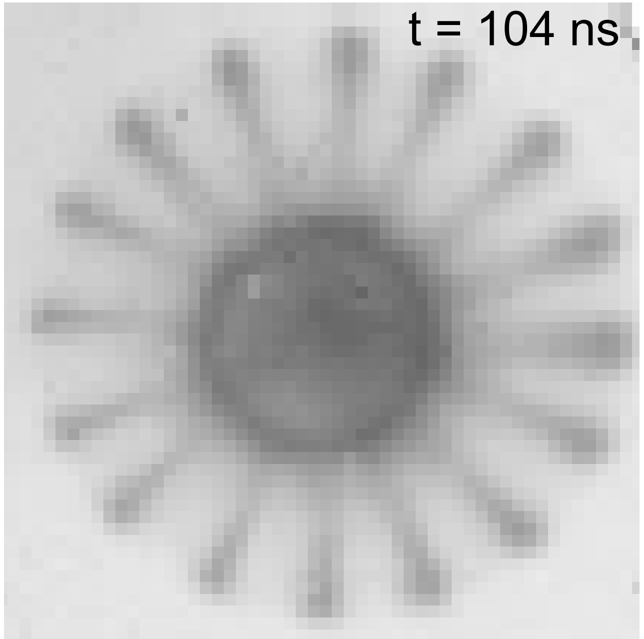
Comparison of experimental and numerical data





16-wire Al array:
results obtained on
COBRA-generator
(Cornell University)

16-wire W array



CONCLUSIONS

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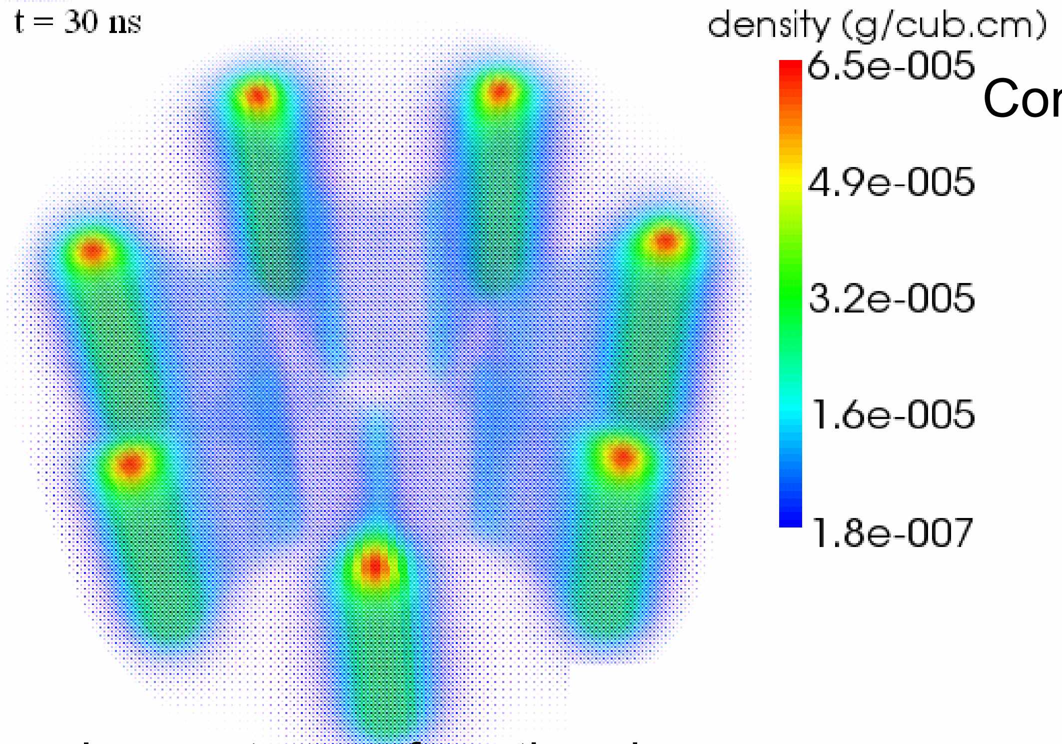
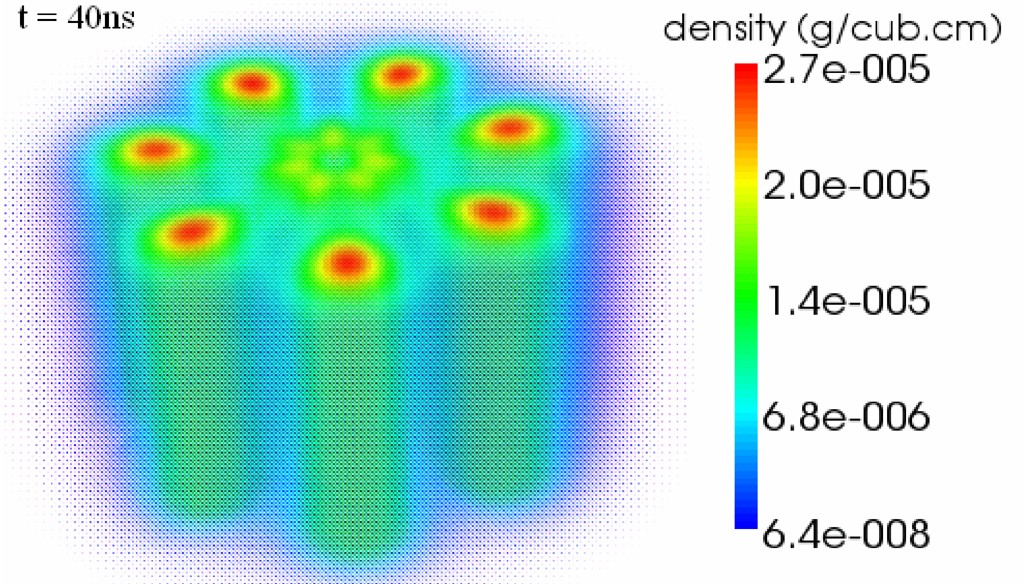
T

N

Compression of 7 tungsten wires array

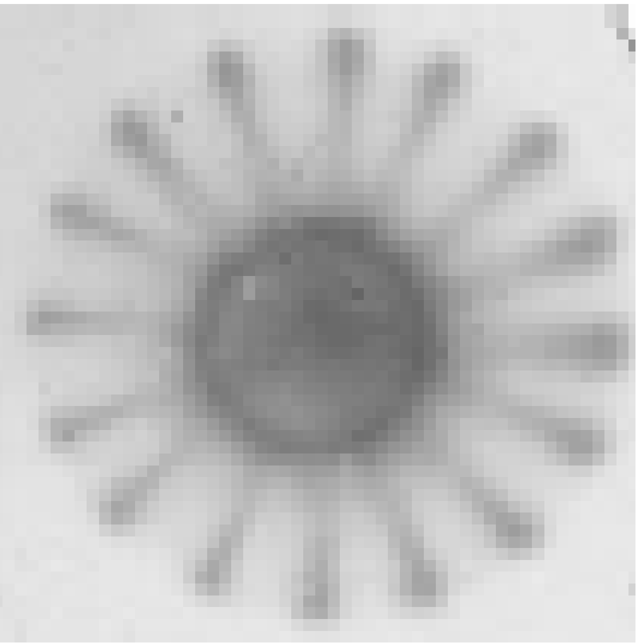


plasma streams from the wires

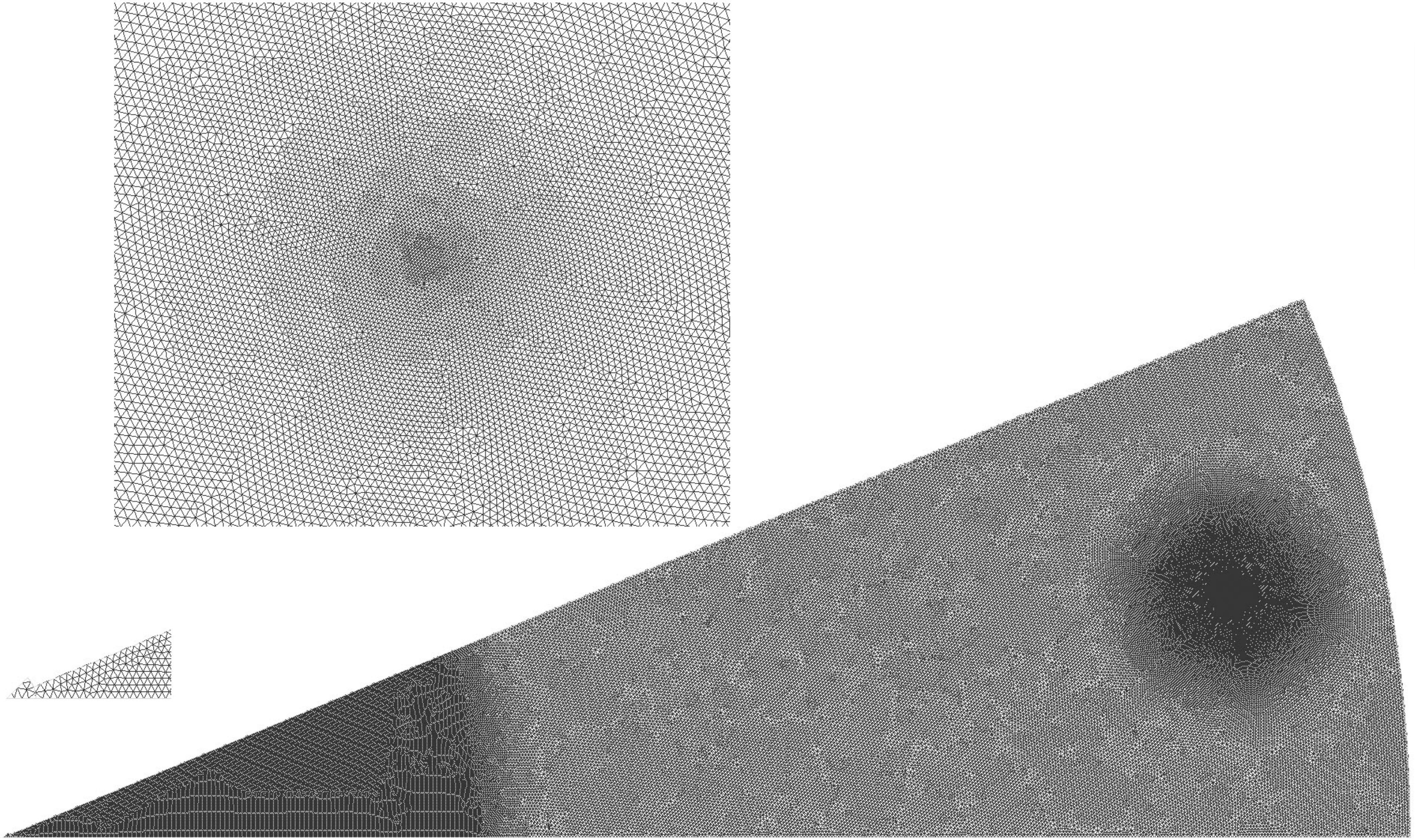


precursor column formation

16-wire W array



$\Delta r_{max} = \Delta z_{max} = 20\ \mu m$, $\Delta r_{wire} = 7.5\ \mu m$
N ~ 20000000



Thank you for your attention